Human Ability and Openability: Producing Design Limits for Consumer Packaging

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Introduction

Traditionally, packaging was designed to preserve and protect the goods it contained and catch the eye of a consumer. In order to achieve these objectives, strong, tight seals were often used, and opening instructions were kept to a minimum. This meant that there were numerous types of packaging that many consumers found difficult to open.

More recently, the focus has shifted to the demands of the consumer rather than those of the manufacturer. The main drivers behind packaging design used to be that of cost to the manufacturer and potential impact on consumers. Nowadays however there is the additional factor of openability. In a recent survey conducted by a consumer magazine, 99% of the responses said that packaging has got more difficult to open in the last 10 years. Difficulties with perception can obviously be a problem for newer types of packaging, with consumers unable to understand instructions or find pull tabs etc. However there are still openability issues with more established forms of packaging that have been in use for many years, such as glass jars and bottles. Consumers fail to open these types of packaging purely because they cannot generate the forces required. It is unlikely that these types of packaging will be replaced in the near future, and so work must be done to enable more people to open them more easily. This work is part of a study to try to find low cost and easy to implement solutions to reduce the required opening forces for difficult to open packaging. In order to ensure that the packaging is designed inclusively, it is essential to fully understand the forces that are required to open them and the forces that consumers can generate.

The problem of difficult to open packaging is especially apparent when looking at elderly people or those with a disability. Reduced dexterity and strength mean packaging that a younger, fitter or healthier person might have no trouble opening become impossible to gain access to. For example, an average 70 year old has similar strength to that of a ten year old child (DTI, 1999). The average age of the UK population is also steadily increasing due to longer life expectancy and other demographic changes (ONS, 2002). The average strength of the population is therefore decreasing. It is estimated that by the year 2020, 50% of the UK adult population will be over the age of 50 (UK Government Actuary Population Predictions).

Research Drivers and Aims

Packaging, along with many other items, is often designed so that it can be operated effectively by the 95th percentile person. Tables of specific strengths and human body dimensions are available from various sources, including Adultdata and Older Adultdata from the DTI and the PeopleSize 2000 database (Open Ergonomics Ltd). These can be used to ensure that designs should be accessible to all. However, many of the tests that have been used to measure the data do not accurately represent the actions used to open packaging, and are therefore unsuitable for use in its design. The tests used also do not allow for any physical problems people might have – arthritis may prevent a user from using a certain form of grip for example, so they might have to resort to using a less effective, weaker grip for opening. Changing population demographics mean that 95th percentile data from tests carried out in the past may not accurately represent the true strength of the current population. These factors mean that existing generic strength data will over predict the forces that people can apply to packaging. Basing product design limits on these predictions will therefore exclude many people that should have been in the target groups.

In order to design inclusively, studies must be carried out to exactly determine the forces that a consumer can apply. It is not merely enough to make the product easier to open; testing must be done to ensure that the packaging can be operated by the entire target group. Therefore experiments need to be carried out to accurately determine the specific forces that people can apply when opening different forms of packaging. Further, the tests need to account for the materials and geometry of the packaging, and also any problems that potential users may have with their operation. This will allow design limits to be determined that will ensure consumers will be able to open products.

For the purpose of this paper we will consider the wide mouth vacuum lug closure (as found on many jam or sauce jars) as a case study.

Previous Work

There have been several prior studies designed to measure the torque that a person can apply to a jar lid. However there are areas that could be improved with each of the tests. Studies by Imrhan (1988) and Rohles (1983) involved tests that were not representative of jar opening as they used fixed lids that were twisted with only one hand.

In 1999, work by the DTI identified that the strength decreases with age. No specific testing was done however. In 2002, the DTI published data related to the strength of people with dexterity disabilities. They used an instrumented replica jar to test opening strength at various diameters, and identified that disabled subjects could generate around 40% of the torque produced by a non-disabled person in the trial. However, they changed the materials used for the test jar, and hence also changed its weight and surface finish. The material used to make the test equipment is important, because the friction forces between surfaces depend on the materials in contact and the surface finish of those materials. By using different materials to the ones used to make jars, the friction between a user's hand and the test device will be different to that between the user's hand and a jar or lid. This means that unless the test device is made from the same materials as the jars (or preferably from actual jars) the test will not accurately measure the actual force that a person could apply to a real jar. By altering the weight of the device they introduce another uncontrolled variable. The weight of the test piece may also affect the torque that a person can apply to the lid.

Crawford et al (2002) found that the diameter of a lid affects the torque a user can apply. They also found users can apply more torque to square lids than round lids. However the test pieces used were made of nylon and were fixed to a hand held metal torque meter. Different diameter nylon lids were used, but the size of the torque meter was constant for all the tests. The results obtained therefore cannot be used with certainty as these changes will affect the appliable opening torque.

In a study in 2002, Voorbij and Steenbekkers used a jar replica similar to that used by the DTI to test the maximum torque that could be applied to a 66mm jam jar lid. However the test jar used was again made from different materials to real jars, and hence the results will be inaccurate.

Fowler and Nicol (1999) developed a transducer to measure the forces acting in 3 dimensions on a single finger during everyday activities including opening a jar. They only measured the force on one finger under a set torque however, and did not measure the torque that a subject could apply. Chadwick and Nicol (2001) also developed an instrumented cylinder to measure the grip force during a variety of simulated household tasks. However the cylinder diameter was only 30mm and so the data obtained cannot be related to jar opening.

Only a small proportion of the data collected has been from people aged over 80, and so despite the growth in number for this demographic, the needs of the older consumer have not been considered.

Apparatus Used

In order to measure the actual torque that people can apply to a jar lid, a torque sensor was embedded into a modified glass jar. To ensure that the actual torque that can be applied was found, the jar lid and the outer surface of the glass jar were kept unchanged. A label was applied to the outside of the jar. The weight and appearance of the device was also considered – the weight was within 4% of a full jar and looked as similar as possible to the original product. This was to try to ensure that a subject's behaviour in the test would be as similar as possible to their behaviour when opening a real product.

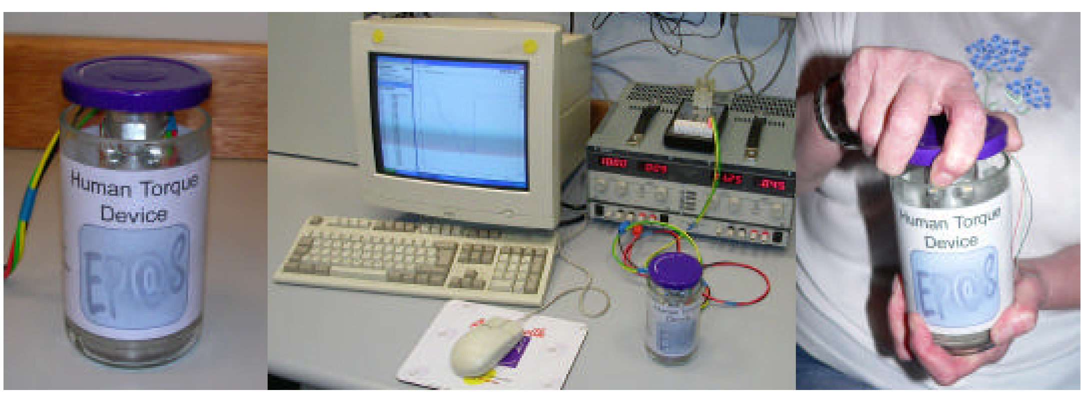

Figure 1. Photographs of the torque device (left), the test equipment (centre) and the device in use during a test (right).

The torque sensor was connected to a computer so that a graph of the torque applied to the lid against time could be obtained (figure 1). The torque sensor used was designed to compensate for any lateral forces that the user might apply, so that only the actual torque applied was measured.

Method

The tests were carried out several different occasions. Each subject was tested individually, and asked to open the jar as they normally would (figure 1). They were not told that the jar lid would not open to ensure that they put in maximum effort. Subjects chose whether to stand or sit for the test, and could pick up the jar or leave it resting on the table. No type of grip was suggested, and multiple attempts using different postures or grips were allowed. Subjects were encouraged during the test to make sure that they applied the highest torque that they could, but were instructed to stop if they felt any pain or discomfort during the test. After taking the test, the subject was shown the computer output. If they felt they had not used their maximum torque they were given the option of repeating the test. The peak torque applied by each subject was then calculated and recorded together with the age and sex of the participant.

Results

In this study, 198 people were tested (84 females and 114 males). The age of the subjects ranged from 8 to 95 for the women (8 to 93 for the men) and there was an approximately even spread of subjects across the ages ranges. The peak applied torque was calculated for each test, and then a mean value for applicable torque was calculated for each decade. The results can be seen in figure 2 below. For comparison the mean opening torque for a sample of the type of jar used is also shown.

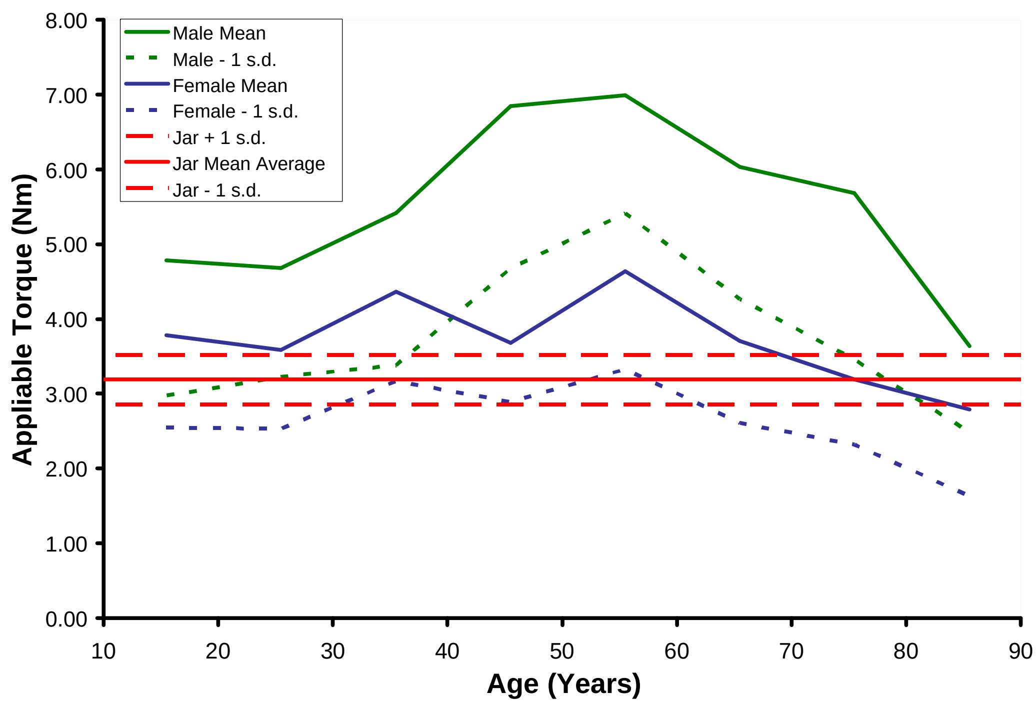

Figure 2. Graph of mean appliable torque against age for 75mm vacuum lug closure.

As can be seen from the graph, much of the female population will struggle to open some jars. At age 75, the mean strength for females drops below the mean jar opening torque. More than half the female population over 75 will therefore be unable to open 50% of the jars they buy. As age increases further the problem worsens, and by age 85 they will only be able to open around 1 in 10 jars. Males are considerably stronger than females, and most men should not struggle to open the bulk of jars. However over the age of 75 strength begins to decrease rapidly, and so many older men will struggle to open some jars.

Validation

The results obtained followed the same general trend as those found in other publications, such as 'Strength Data for Design Safety' (DTI 2000) and the study by Voobij and Steenbekkers. The values found agree well below the age of 60. However, above this age the data from the other studies does not exhibit the same drop in strength as observed in this test. The values found are consistently lower than those found by Rohles (1983). This implies that the test is accurate and that the existing data overestimates the strength of the elderly population.

The results can also be compared with the results of various surveys of the population. A packaging survey in 'Yours' magazine, aimed at the retirement age group, stated that over 70% of the 2,000 candidates have had to abandon a product they were unable to open, and 91% needed to ask for assistance to open a package. Although these figures cover packaging of all types, jars were second on the 'worst thing to open' list. These statistics fit well with the values found in testing.

In a survey of those taking part in the study, many of the elderly subjects also indicated that they had trouble with jars, with some even stating they would not buy jars as they could not open them. A number of female subjects across the entire age range also said they had problems with some jars, as the results suggest they would. Few male candidates under the age of 70 complained of difficulty with jars. Again this agrees well with the data, and suggests the results are accurate.

Conclusion

The forces that a human can apply are dependent on many factors. The age and physical condition of the subject greatly influence the amount of force that can be generated. As age increases past 60, strength begins to reduce rapidly. In order to ensure that packaging can be opened by all, it must be designed with the weakest consumers in mind.

The force that can be applied to a package is also very dependent on the packaging itself. Even seemingly small changes in materials or geometry can have a large impact on the forces a consumer is able to generate. Specific testing is therefore required to determine the forces that a consumer will be able to apply to a specific package. When the strength of the weakest consumer in the target group has been established, design limits based on the strength of that weakest user can be set. If these design limits are then adhered to, it will ensure that all consumers in the target group will be able to open the package.

The authors believe that in order to design inclusively, it is important to fully understand the ability of the target users and the forces required to open packaging. It is not enough to make a product easier to open and call it 'inclusive'. Specific tests must be done to make sure all the target market will be able to open a product.

Further Research

Lid diameter affects the torque that a user can apply to a jar lid, with torque increasing with diameter until it reaches a peak, then beginning to decrease with further increases in diameter (Crawford, 2002). At this peak diameter, the user can apply their maximum possible torque. Lids of this diameter should therefore be the easiest for consumers to operate. In order to determine the optimum diameter for a closure, further testing is required using devices of varying diameters.

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